REMARKS

The application is believed to be in condition for allowance.

The Appendix includes 1) Fujisaki et al.: "Fundamental Electromagnetic Characteristics of In-Mold Electromagnetic Stirring in Continuous Casting" and an abridged translation of JP '518. These have previously been provided, but are being again provided as a convenience to the Examiner. Fujisaki et al.: "Fundamental Electromagnetic Characteristics of In-Mold Electromagnetic Stirring in Continuous Casting" (hereinafter, the "Fujisaki Paper") is a report from "International Symposium on Electromagnetic Processing of Materials", 1994, Nagoya, ISIJ (Iron and Steel Institute of Japan), pages 272 to 277. This paper was previously submitted in an IDS and considered on May 13, 2005.

There are no formal matters outstanding.

Claims 1, 4, and 10 are independent.

The claims stand rejected as anticipated by JP 6182518 (JP '518).

The independent claims are believed patentable in that the reference neither teaches nor suggests the features of the claims. Further, the dependent claims are believed to be patentable both for depending from an allowable independent claim and for reciting features of the invention both novel and non-obvious over the prior art.

Consider claim 10 first.

The features of claim 10 have not been addressed by the Official Action. More specifically, claim 10 requires:

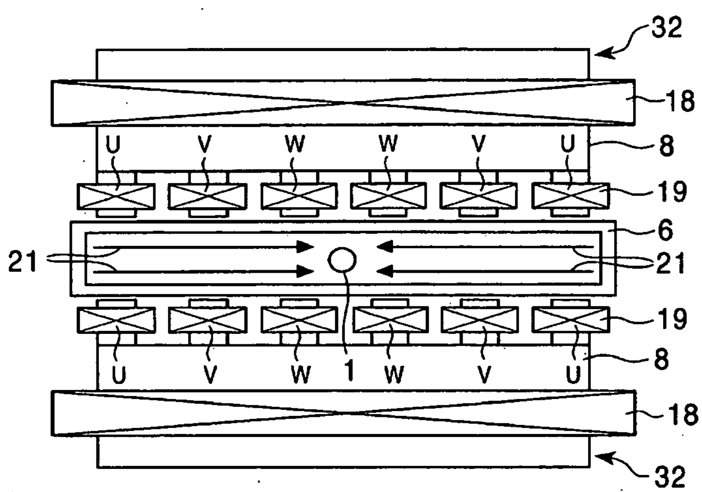
"means for applying magnetic fields at positions above and below an ejection port of an immersion nozzle; and"

"a first coil for **producing an AC magnetic field moving in a longitudinally symmetrical relation from opposite ends to a center of said mold along a longitudinal width thereof**, and a second coil for producing a DC magnetic field, both said first and second coils being wound over each of common iron cores,"

"said iron cores being arranged on opposite sides of said mold along a transverse width thereof such that a direction of the magnetic fields produced by said coils is aligned with the transverse width of said mold."

See Figure 17A, reproduced below:

FIG. 17A



The Fujisaki Paper and JP '518 both disclose a driving force from one end to the other end. See JP '518 Drawing Figure 8(b), [0031] and [0032]. The arrangement in JP '518 Fig. 8(b) does not produce the recited AC magnetic field moving in a longitudinally symmetrical relation from opposite ends to a center of said mold (Fig. 17A of the present application) to prevent the problem shown in Fig. 14 (see page 28, line 20 to page 29, line 3).

Thus, claim 10 is not anticipated.

Consider claim 1, which claim recites "electromagnets each comprising an iron core and a coil wound over said iron core, said electromagnets being arranged in a facing relation on opposite sides of said mold along a transverse width thereof to lie side by side along a longitudinal width of said mold; and means for supplying a single-phase AC current to each coil."

Claim 4 recites "a coil supplied with a DC current for producing a DC magnetic field and a coil supplied with a single-phase AC current for producing a non-moving, vibrating magnetic field, both said coils being wound over each of common iron cores".

Thus, independent claims 1 and 4 each recite that the AC being supplied to the coils is a single phase AC current. Some claims further require a continuous current.

JP '518 discloses to apply a discontinuous pulsed DC current ([0029], see also Fig. 2, and [0015]). Therefore, JP

'518 does not itself disclose or suggest AC current or DC current in the normal meaning of these terms. To the extent that AC is mentioned, JP '518 only shows an example based on hypothetical <u>three-phase</u> AC current ([0012] and Drawing 7).

The Official Action does not disagree or take issue with this evaluation of JP '518. Rather, the Official Action rejects the pending claims, stating that JP '518 "is capable of generating a single phase and continuous" (last sentence of OA page 2 and page 3, Response to Arguments).

Applicants respectfully disagree. Further, the Official Action's statement that JP '518 "is capable of …" is statement that JP '518 could be modified to generate a single phase AC current and this is itself an implicit acknowledgement that there is no disclosure of providing the coils with a single phase AC current. Thus, there is no anticipation.

Applicants also respectfully disagree as to JP '518 being capable of generating a continuous single phase AC current.

Applicants appreciate that they may not understand the Examiner's viewpoint and have asked for a personal interview to discuss JP '518. However, since an interview has not yet been possible, to explain why the Official Action is incorrect, applicants refer to the attached Fujisaki Paper. The Fujisaki Paper provides the state of the art in the field of electromagnetic stirring of molten steel in the mold for

continuous casting. See the below separate discussion as to the Fujisaki Paper.

The Fujisaki Paper

The Examiner asserts that three-phase AC current of JP '518 is capable of generating a single phase.

Case A: It seems that the Examiner considers phase current supplied to each coil as single phase current. However, this is the typical way to supply multiphase current to electromagnetic coils to form linear induction motor as seen in the Fujisaki Paper. In other words, supplying multiphase current means that totally two or more phase currents (i.e. phase current having different phases, except for 180° resulting from reverse connection) are provided to the coils, and it is not necessary to apply two or more phase currents to a single coil. Therefore, for the skilled person in the field of electromagnetic stirring of steel sheet, the mutually exclusive term of "supplying single phase current" means that only one phase current (reverse connection is allowed) is supplied to every coil.

See that claim 11 defines the phase difference between adjacent coils that clearly distinguishes single phase current with multiphase current.

Case B: It may also be possible that the Examiner considers that the apparatus as it is (in JP '518) could provide a single phase current to the coils. However, to provide a

single phase current (i.e. same phase for every coil), either a connection (between the coil and pulse generator) or an output of the pulse generator must be modified. Further, such modification loses linear driving force to the molten steel, and therefore is precluded in JP '518, besides the fact that JP '518 clearly designates phase number of three or more.

Case C: Or, the Examiner might simply believe that selection of single phase AC current source could be replaced with the three-phase current in the apparatus disclosed in JP '518, as knowledge of skilled in the art. However, there is no reasonable basis for such assumption and this would be an issue of obviousness rather than anticipation. Further, as pointed out in Case B, this replacement is clearly precluded by JP '518 itself. Also note that as disclosed in the Fujisaki Paper, it is common sense to use multiphase current source.

Detailed Demonstration: Case A

In the Fujisaki Paper, typical electromagnetic stirring method is disclosed. The stirring coil is supplied with alternative current and multiphase power source, and makes the traveling flux (page 272, Item 2, second paragraph). In other words, the stirring coil forms the primary part of the linear induction motor (page 272, Item 2, first paragraph).

As the number of the phase current, the 3-phase and 36-phase is studied (page 277, Item 4-5), but 3-phase is mainly

studied. A source of "three phase current" has three output terminals, and an alternative current (phase current) is provided between each two terminals. This phase current has displaced phases (by 120°) from each other, and named as u-, v-, and w-phase (page 274, Table 1 (comment is in page 272, 5^{th} to the last to second to the last line), and page 277, Item 4-4). Note that reverse connection (i.e. opposite current direction) to the coil is possible ("-u", "-v" and "-w"), and therefore six phase currents which differ from each other by multiples of 60° are available (page 277, Item 4-4). As suggested in Item 4-4, each of the electromagnetic coils is connected to two of the output terminals, and one of the six phase currents u, -u, v, -v, w and -w is provided to the coil. This means each one of the coils is supplied with a phase current, which is multiphase (page 272, Item 2, second paragraph).

The method (and apparatus) disclosed in JP '518 is based on the method disclosed in the Fujisaki Paper. As disclosed in paragraph [0012], each electric coil is linear motor energization by m-phase (specifically explained using the case of m=3), where m is 3 or more ([0007]). The alternating current wave corresponding to necessary driving force is supplied ([0012]). Specifically, waves of electric current shown in Drawing 7 (page 7/8 in the computer translation attached to the first response), which also differs from each by a multiple of 60° and therefore substantially serves as phase currents of three

phase supply, is supplied to coils as disclosed in [0021], [0023], [0024], [0031] and [0032].

Therefore, the current shown in Drawing 7 (or Drawings 6, 9 and 10) is defined as a phase current of multiphase current. There is no disclosure of a single phase current.

On the other hand, in this present application, only one phase current (reverse connection is allowed) is supplied to every coil as seen in Figures 2 and 3 and page 11, line 15 to page 7, line 7 in this specification. This is what the skilled person in the field interprets "supplying single phase current".

Detailed Demonstration: Case B

As demonstrated in above Item 2, JP '518 clearly limits m (phase number of supply) to be 3 or more ([0007]). Therefore, three-phase AC current of JP '518 is not capable of generating a single phase, unless the specifically disclosed apparatus in JP '518 is capable of generating a single phase without substantial change. As far as we understand, substantial change is necessary to supply single phase by the apparatus disclosed in the drawings.

For example, in Drawing 3, each of function generators 81 to 86 is clearly structured to generate phase current that differs phases from each other ([0031] to [0032]). Therefore, either:

- changing connection so that only two of the generators (such as 81 and 84, corresponding to reverse connection with each other) provides output to every coil, or

- synchronizing every function generator (by, for example, using only Pa and P_{b180} as the pulse for clearing address counter 617 in Drawing 4) (see [0021], [0023], [0024]), which means <u>changing</u> input pulses by replacing P_{b60}, P_{b120}, P_{b240}, and P_{b300} into Pb0 or P_{b180}, is necessary to make the apparatus function as a single phase current generator.

Each method clearly changes the structure of the apparatus from what is disclosed in JP '518.

Furthermore, such change clearly conflicts with the teaching of JP '518 that linear driving force for molten metal ([0012]) that applies the force to move right to left or left to right along the long side of the mold ([0031] and [0032]) must be generated. As shown in the Appendix filed with the first response, the claimed apparatus (except for claim 10) having single phase current source does not generate such linear driving force. See also Figures 2 and 3 and page 11, line 15 to page 7, line 7 in this specification.

<u>Detailed Demonstration: Case C</u>

As demonstrated in above Item 3, alternating current source to single phase clearly conflicts with the teaching of JP '518. Besides, the apparatus in the drawings (especially in

Drawing 3) has six function generators for cyclic wave, while it would have been much simpler if only one generator were applicable. This also shows that single phase source is out of the concept and not suggested.

In the Fujisaki Paper, it is said that the stirring coil is supplied with alternative current and multiphase power source, and makes the traveling flux (page 272, Item 2, second paragraph). Fujisaki discloses two phase numbers, i.e. 3-phase and the maximum phase for the model case (36-phase). It also implies that 3-phase is the minimum phase in commercial use. (Theoretically, 2-phase current having phase displacement of 90° can generate linear driving force, but it is not so convenient as 3-phase).

The Pending Rejection

As an initial matter, it is noted that the Official Action states that JP '518 discloses an apparatus "capable to supply AC current to each coil" (OA page 2) and "Applicant argues that JP '518 discloses a three phase and not a single phase. However, the Examiner respectfully disagrees, since applicant is claiming an apparatus and wherein the three-phase AC current of JP '518 is capable of generating a single phase." (OA page 3).

Consider claim 1, which claim recites "electromagnets each comprising an iron core and a coil wound over said iron core, said electromagnets being arranged in a facing relation on

opposite sides of said mold along a transverse width thereof to lie side by side along a longitudinal width of said mold; and **means for supplying a single-phase AC current to each coil**." Thus, the recitation is of supplying a single-phase AC current to each coil and is not directed to merely generating a single phase AC current.

In this regard, see that claim 11 requires that a phase difference between a pair of adjacent coils on the same side of the mold is 0° or 180°. Thus, it is clear that the claims do not read on a three-phase current being applied to the coils. The Official Action does not disagree with this position, but rather states that JP '518 is capable of supplying a single phase AC to each coil.

Thus, the rejection is not actually based on the disclosure of a single phase AC but rather the rejection is based on JP '518 being capable to supply a single phase AC to each coil. As such, the rejection should be an obviousness rejection.

However, to provide a single phase current (i.e., the same phase for every coil), either a connection (between the coil and pulse generator) or an output of the pulse generator must be modified. Further, such modification loses linear driving force to the molten steel, and therefore is precluded in JP '518. Additionally, there is no motivation (in the prior art) for making this modification.

The independent claims are neither anticipated nor rendered obvious by JP '518.

Claims 3, 12 and 13

Regarding claim 3, the Official Action states that JP '518 discloses an iron core comprised of comb-shaped iron core having comb-teeth (OA page 2). But claim 3 recites "wherein said iron core comprises a comb-shaped iron core having a comb-teeth portion over which said coils are wound and a root portion over which a second coil is wound, and further comprising a means for supplying a DC current to the second coil" and JP '518 fails to disclose or suggest the combination of first coil wound on comb-teeth portion of the comb-shaped core supplied with an AC current and the second coil wound on the root portion of the core supplied with a DC current.

Claim 12 requires the means for supplying a single-phase AC current is a means for supplying continuous single-phase AC current. Claim 13 also a continuous current.

The JP '518 device does not supply a continuous current but rather supplies a discontinuous current. See [0018] and [0021] as well as Drawing Figure 6. Figure 6, although generally a sine wave, is a discontinuous wave.

Thus, these claims are also not anticipated.

Reconsideration and withdrawal of the pending anticipation rejection are respectfully solicited. Allowance of all the claims is also solicited.

Applicants believe that the present application is in condition for allowance and an early indication of the same is respectfully requested.

Should there be any outstanding issues, it is requested that the undersigned attorney be contacted to arrange an interview in order to resolve these.

The Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 25-0120 for any additional fees required under 37 C.F.R. § 1.16 or under 37 C.F.R. § 1.17.

Respectfully submitted,

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APPENDIX:

The Appendix includes the following items:

- Fujisaki et al: "Fundamental Electromagnetic Characteristics of In-Mold Electromagnetic Stirring in Continuous Casting", and

- An abridged translation of JP '518.

International Symposium on Electromagnetic Processing of Materials, 1994, Nagoya, ISIJ

FUNDAMENTAL ELECTROMAGNETIC CHARACTERISTICS OF IN-MOLD ELECTROMAGNETIC STIRRING IN CONTINUOUS CASTING

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Synopsis : Fundamental electromagnetic characteristics of in-mold electromagnetic stirring in continuous casting are analyzed by means of the finite element method of electromagnetics. The in-mold electromagnetic stirring has many electrical parameters such as pole number, frequency, stirring direction, relative space phase of two coils, number of phases. The electromagnetic force is important to drive the molten metal and to improve the metal quality. In this paper the electromanetic characteristics are shown in the evaluation of the electromagnetic force distribution and the norm of electromagnetic force vector in molten metal mold.

Key words : linear induction motor, in-mold stirring, continuous casting, electromagnetic force, pole pitch, frequency, space phase, number of phases

1. Introduction

In-mold electromagnetic stirring in continuous casting has been developed for about 20 years[1], and got a lot of superior quality in slab surface and metallurgical characteristics[2]. However, the users' demand for high quality steel and the cost reduction is necessary for the high metallurgical quality in continuous casting process[3]. Then the in-mold electromagnetic stirring in continuous casting is expected to be one of the most important technology to control the initial solidification to get the clean slab surface and the low number of non-metallic inclusions[4]. In order to get the optimal design and operation of the in-mold electromagnetic stirring, the numerical method is a superior one to get the fundamental characteristics. In this paper, the electromagnetic charactreristics are shown by finite element method of electromagnetics as the parameters of the in-mold electromagnetic stirring.

2. Electromagnetic calculation

The in-mold electromagnetic stirring is used to control the initial solidification of molten metal in mold of the continuous casting. The stirring coils are installed inside the both sides of the mold as shown in Fig.1. The stirring coil is treated as the primary part of the linear induction motor and the molten steel is treated as the secondary part.

The stirring coil is supplied with alternative current and multiphase power source, and makes the traveling flux to the molten steel in the mold. Then the eddy current is induced in the molten steel, and the electromagnetic force is induced as the Lorentz's force.

The analysis of the linear induction motor has been made for several 10 years and a lot of items were made clear by many researchers[5,6]. However, the linear induction motor mentioned in this paper has several different items from the usual linear induction motor which is researched.

1).In case of railway application, the characteristics of linear induction motor is evaluated by the total force integrated through the volume[7]. However, in case of stirring application, since the electromagnetic force induced by linear induction motor operates the molten metal, the electromagnetic force distribution is important.

2).The two coils are arranged one by one, and the mutual electromagnetic coupling should be considered. Moreover, we must select the moving direction of traveling flux in the two coils.

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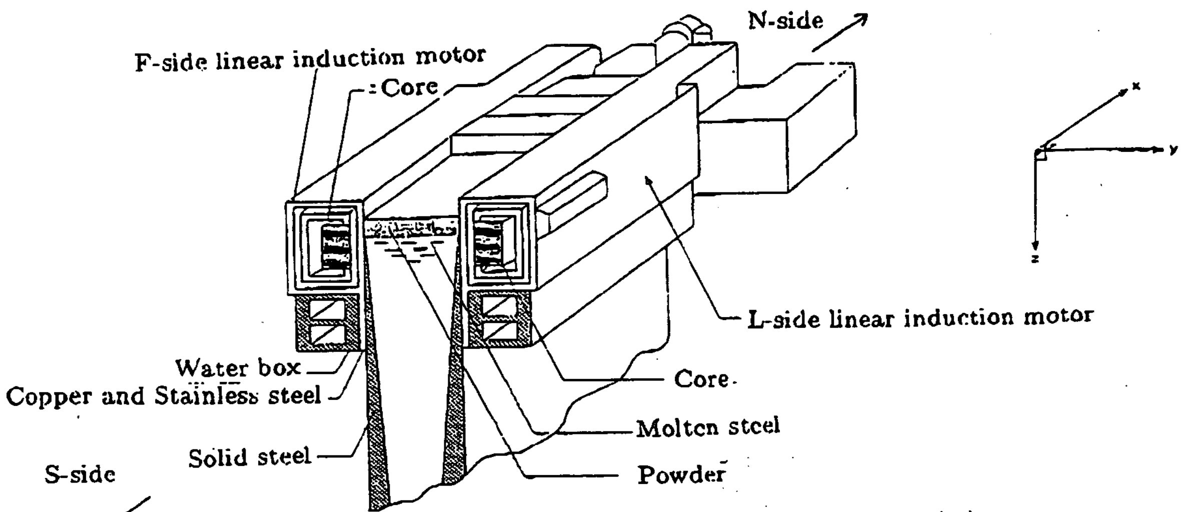

Fig.1 Schematic veiw of in-mold electromagnetic stirring.

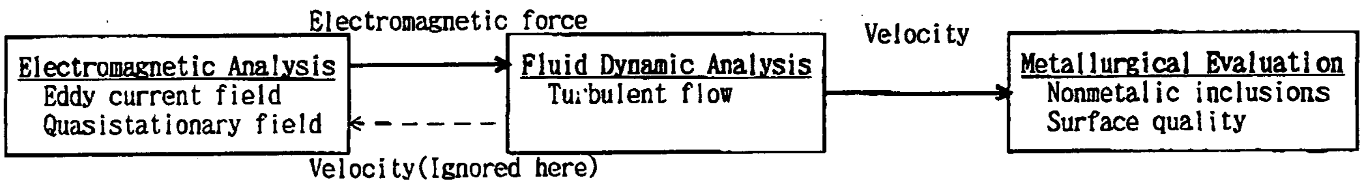

Fig. 2. Magnethydrodynamics of in-mold electromagnetic stirring.

3).Since the coils are coil-winding type, the connection of each slot's coil is changed easily. In other words, the change of pole number, relative space phase can be done in no special work (no rewinding work of slot coil).

4).Since the electromagnetic force is not the last evaluated item, the flow dynamics calculation is necessary as the medium evaluation index between the electromagnetic analysis and the metallurgical evaluation. However, the stirring force is treated as the the actuator of the stirring process. Then the electromagnetic characteristics is important in order to improve the flow dynamics.

5).There is a mold made of copper and stainless steel between the molten steel and the stirring coil in order to cool the molten metal and to support them. Therefore, the electromagnetic screen phenomena occurs in this process.

Though usually the velocity electrical motive force term often has some important role in the electromagnetic phanomena, this term is almost negligible in this process. The synchnous speed of linear induction motor (traveling speed of electromagnetic flux, about 3m/s) is large enough as the maximum part velocity in the molten steel (about 0.2m/s)[8]. In other words, the molten steel seems to stop from the point of view of the traveling speed of electromagnetic flux. Therefore, the effect of the velocity by fluid dynamics analysis to the electromagnetic field is almost negligible.

Therefore, the magnethydrodynamics calculation procedure of the in-mold electromagnetic stirring is that the electromagnetic force distribution is calculated first, and then the fluid dynamics is calculated second as shown in Fig.2.

The electromagnetic calculation method is finite element method and A-ϕ method. The displacement current in Maxwell equation is ignored, and the quasistaionary field is assumed(time partial differential is treated as $j\omega$)[9].

The phase unbalance in power source, which occurs usually in linear induction motor, is ignored here. The DC resistance component is large enough to ignore the AC impedance component as shown in Table 1, because the supplied frequency is very low like a few Hz. Therefore, the phase balanced current source is used in the calculation.

Analytical model is shown in Fig.3 and the material constants used here are shown in Table 2.

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Table 1. Phase current and voltage

Voltage between U and V phases	128V	U-phase current	539A
Voltage between V and W phases	137V	V-phase current	542A
Voltage between W and U phases	143V	W-phase current	544A

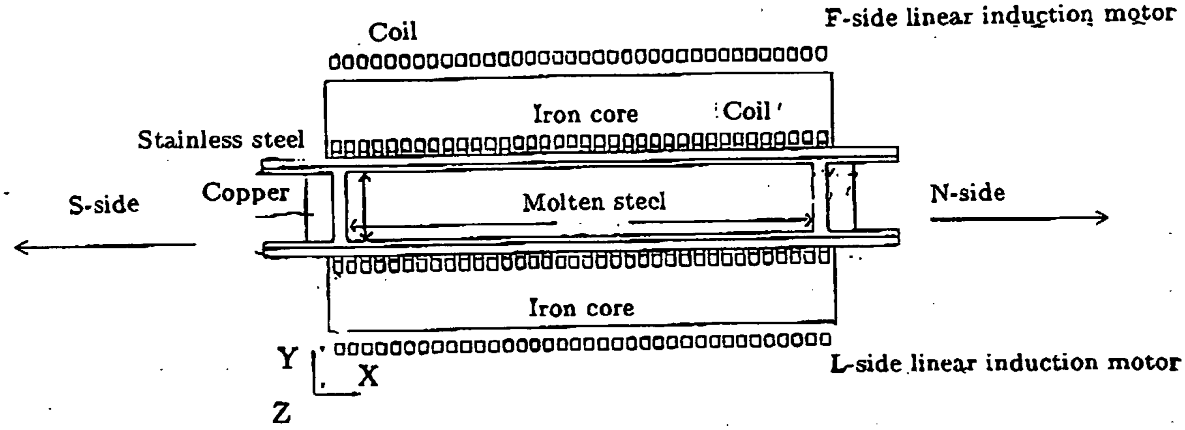


Fig.3 Analytical model of in-mold electromagnetic stirring (top veiw).

Table 2. Material constants used here.

Materials	Relative permiability [-]	Conductivity [S/m]
Molten steel	1	$7.69*10^6$
Copper	1	$1.78*10^7$
Stainless steel	1	$1.33*10^6$
iron core at coil	1000	0.0

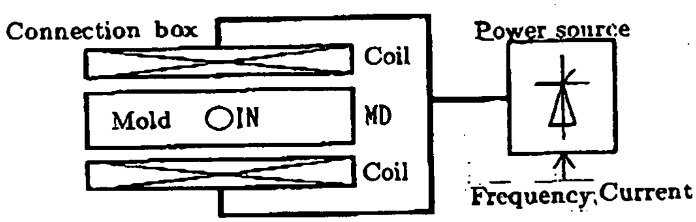


Fig.4 Electrical structure of in-mold electromagnetic stirring.

The electrical structure consists of coils and power source as shown in Fig.4. The stirring coils have some parameters such as stirring direction(rotating stirring, parallel strirring), pole number, relative space phase. The power source has some parameters such as current, frequency, phase number. Therefore, the characteristics of each parameter are important to get the flow control of the in-mold electromagnetic stirring.

3. Calculation tool identification

To confirm the usefullness of the calculation model, we compare the calculation data and the experimental data by 3-dimensional model as shown in Fig.5. The magnetic flux density is measured at the empty mold. The magnetic flux density distribution in 3-dimensions is in good agreement between the calculation data and the experimental data. The z-direction flux density appears in the figure because of the unsymmetry in z-direction of the mold.

The magnetic flux density, eddy current, electromagnetic force distributuin in molten steel are shown in Fig.6. The real part means that the electrical angle is 0deg., and the imaginary part means that the electrical angle is 90deg. The electromagnetic force has direct current component and alternative current component. Fig.6 shows only direct current component.

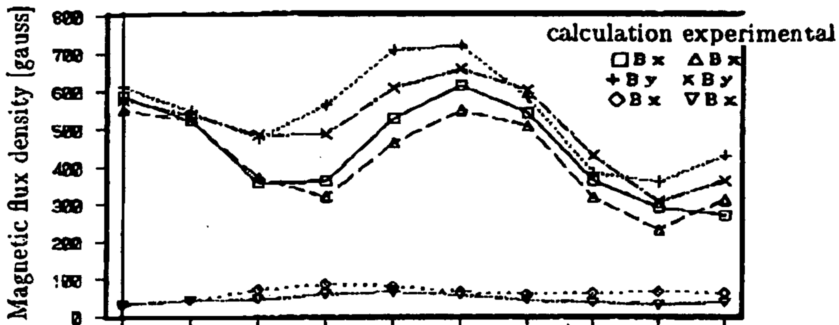
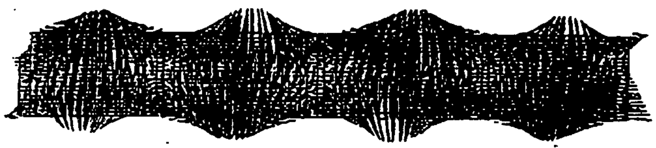
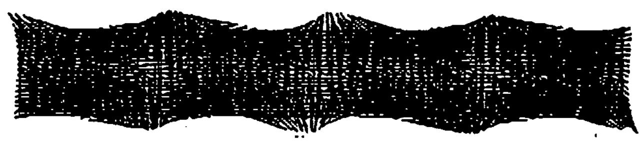


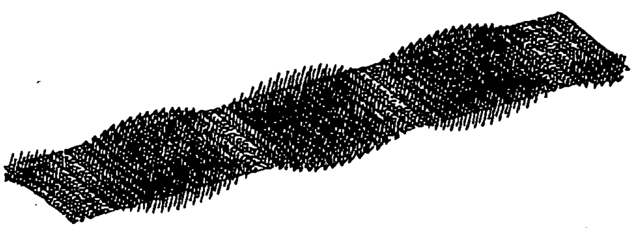
Fig.5 Comparison between calculation data and the experimental data. (Magnetic flux density peak value, Frequebcy:3.3Hz, Current:525A, Pole number:4)



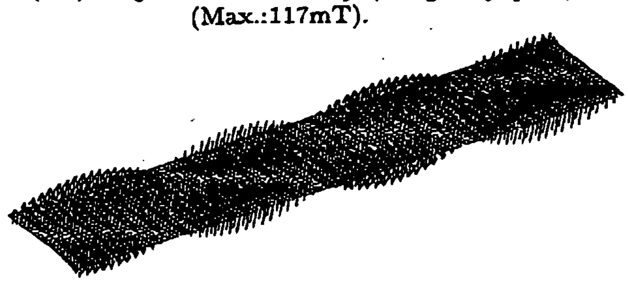
(a-1).Magnetic flux density (real part) (Max.:87.2mT).



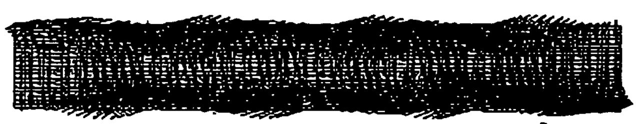
(a-2).Magnetic flux density (imaginary part) (Max.:117mT).



(b-1).Eddy current(real part) (Max.:0.146A/mm^2).



(b-2).Eddy current(imaginary part) (Max.:0.132A/mm^2).



(c).Electromagnetic force(DC components only) (Max.:6.27kN/m^3).

Fig.6 Magnetic flux density, eddy curent and electromagnetic force distribution in mold.

4. Pareameter characteristics

4-1. Stirring direction

The stirring direction in the two coils has rotating stirring mode and the parallel strirring mode. The rotating stirring mode is that the directions of traveling flux are different, and the parallel stirring mode is that the directions of traveling flux are the same. The electromagnetic force distribution in rotating stirring mode has eddy distributions, though the one in the parallel stirring mode has no eddy distribution as shown Fig.7. The interaction of the electromagnetic fields in the both sides makes the non-operated space of electromagnetics field at each pole in rotating mode[10].

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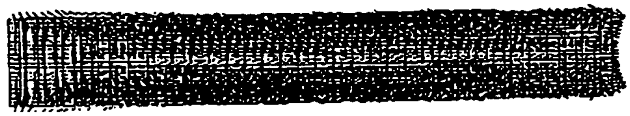
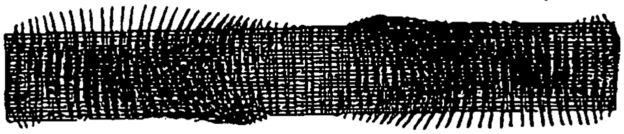
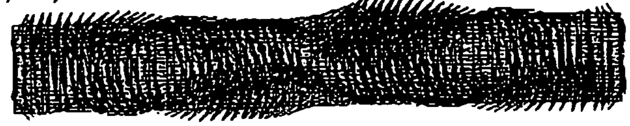
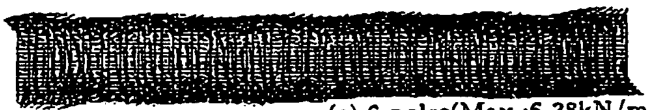
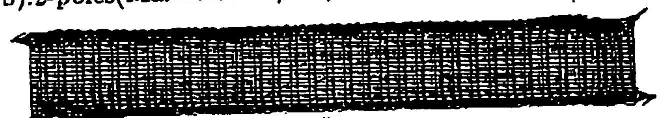


Fig.7 Electromagnetic force distribution in parallel stirring. (Max.:7.51kN/m³).

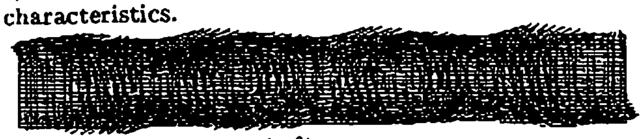



(a).1-pole(Max.:6.2kN/m³). (b).2-poles(Max.:6.69kN/m³).

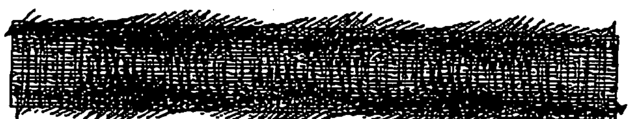



(c).6-poles(Max.:6.38kN/m³). (d).12-poles(Max.:0.78kN/m³).

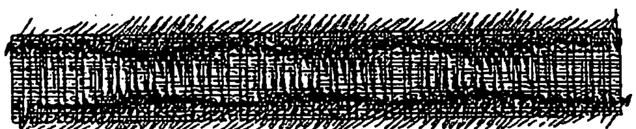
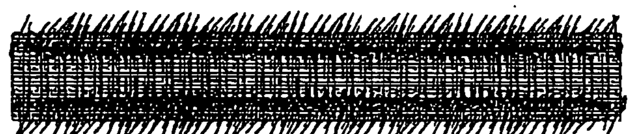
Fig.8 pole number characteristics.

(a).1Hz(Max.:5.24kN/m³). (b).2Hz(Max.:6.27kN/m³).

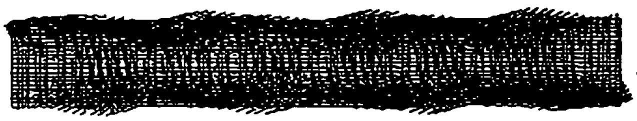
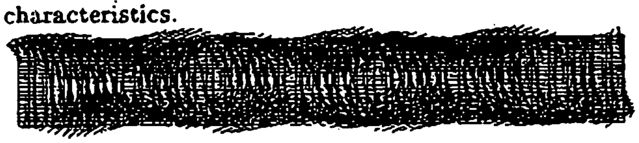



(c).5Hz(Max.:4.74kN/m³). (d).10Hz(Max.:3.16kN/m³).

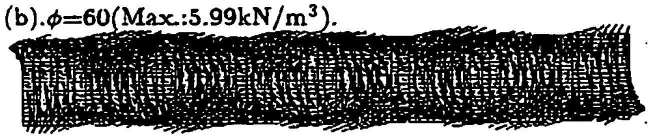



(e).20Hz(Max.:1.96kN/m³). (f).50Hz(Max.:1.14kN/m³).

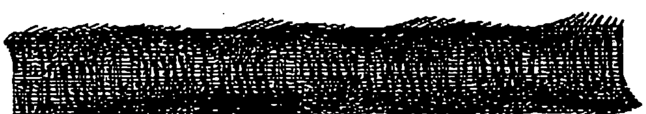
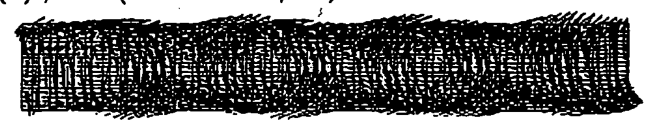
Fig.9 Frequency characteristics.

(a).ϕ=0(same pole)(Max.:6.27kN/m³). (b).ϕ=60(Max.:5.99kN/m³).

(c).ϕ=120(Max.:5.95kN/m³). (d).ϕ=180(Max.:5.91kN/m³).

(e).ϕ=240(Max.:5.95kN/m³). (f).ϕ=300(Max.:5.99kN/m³).

Fig.10 Relative space phase characteristics.


(a).3-phase(Max.:6.59kN/m³). (b).36-phase(Max.:7.08kN/m³).

Fig.11 Phase number characteristics.

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4-2. Pole number characteristics

The pole number characteristics are shown in Fig.8. The lower pole number becomes the longer pole pitch, then the magnetics flux penetrates into the molten metal deeply. Then the center part of the mold has the large electromagnetic force. However, the higher pole number becomes the shorter pole pitch, then the magnetic flux does not penetrate into the molten metal. Then the electromagnetic force is distributed mainly along the longitudinal direction of the mold. The vertical components to the longitudinal direction of the mold of the electromagnetic force decrease according to the increase of the pole number. The electromagnetic force has the eddy distribution, the numbers of which are the same as the pole number.

4-3. Frequency characteristics

Frequency characteristics are shown in Fig.9. In lower frequency, the electromagnetic force penetrates into the mold deeply, and the norm of the electromagnetic force vector is relatively small. The norm of the vector means the norm of the electromagnetic force vector in the mesh of the finite element method. The maximum value in the meshes of the mold is shown in each figure as the maximium value. The vertical component to the longitudinal direction is also small. On the other hand, in higher frequency, the electromagnetic force does not penetrate into the mold, and the electromagnetic force vector's norm becomes small. However, the vertical component to the longitudinal direction bacomes high.

4-4. Relative space phase characteristics

We must select the relative space phase in two coils. When the connection of F-side coil is "u -v w -u v -w" from N-side to S-side and the connection of L-side coil is "u -v w -u v -w" form S-side to N-side, the relactive space phase ϕ is defined as 0deg . The "u,v,w" means the u-phase, v-phase, w-phase respectively, and the minus sign means that the current direction is opposite. When the relative space phase ϕ becomes large such as 60deg. or 120deg. for example, the connection of L-side coil from S-side to N-side is "-v w -u v -w u", "w -u v -w u -v" respectively. Here, the connection of F-side coil is fixed. The relative space phase characteristics are shown in Fig.10.

The eddy positions of electromagnetics force shift in longitudinal direction, according as the relative space phase of the two coils shifts in the same direction.

4-5. Phase number characteristics

The phase number characteristics are usuful for the evaluation of the space harmonic influence, because the single-winding has a lot of space harmonics usually. The number of 36 is the slot's number in the coil. Then the 36-phase is the maximum value in this system.

The 36-phase's electromagnetic force vector's norm is about 10-percents larger than the 3-phase's electromagnetic force vector's norm. However, there is no distinguished difference between the 36-phase's electromagnetic force distribution and the 3-phase's one as shown in Fig.11.

5. Conclusion

It is concluded that the selection of electromagnetics parameters based on the electromagnetic characteristics is important to control the molten metal flow in mold to clean the metal surface.

6. Refecences

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JP 6-182518 A

Abridged translation based on the computer translation by JPO

Underlined portion is not reviewed.

[0005] [Means for Solving the Problem] The flow control unit of the molten metal of this invention comprises; two or more magnetic poles (11-19) arranged along with mold side (1) surrounding molten metal; two or more electric coils (1Aa-3Aa, 1Ba-3Ba, 1Ca-3Ca) for exciting each magnetic pole; an alternating current energization means (81-83; 611,612,615-621 of 61-69; 41-49) to energize the alternating current (Iaa:Aa, Ba and Ca) for a linear drive for carrying out the driving of flow of said molten metal to said electric coil in the array direction of said magnetic pole; and direct-current energization means (613,614,615-621 of 61-69; 41-49) which energizes a direct current (Ib) for braking to brake molten metal to said electric coil.

[0007] The flow control unit of the more concrete embodiment of this invention comprises; 1st, 2nd, ... m x n th magnetic pole (11-19) wherein m>=3 and n>=1, arranged along the mold side (1) which encloses molten metal; -- for exciting each of these magnetic poles the 1st and 2nd .... the -- a mxn electric coil A signal generation means to generate the signal of m ream for forming; linear drive alternating current wave (Aa, Ba, calcium) (81-83); (1Aa, 1Ba, 1calcium, 2Aa, 2Ba, 2calcium, 3Aa, 3Ba, 3calcium) The signal (Aa correspondence) of the 1st ream the 1st, m+1, 2m+1, and .... an electric coil (1Aa, 2Aa, 3Aa) -- a magnification means (612) to amplify with the amplification factor (611 outputs) which was alike, respectively and was addressed -- The means which was addressed to each of these electric coils in the output signal of a magnification means (612) and which carries out bias value (613 outputs) part bias (614). It reaches. the 1st energized to each electric coil by the energization duty corresponding to the signal by which bias was carried out, m+1, 2m+1, and .... coil driver (615 to 621; 41 of 61, 64, and 67, 411-414 of 44 and 47); -- the signal (Ba correspondence) of the 2nd ream the 2nd, m+2, 2m+2, and .... an electric coil (1Ba, 2Ba, 3Ba) -- a magnification means to amplify with the amplification factor which was alike, respectively and was addressed, and the means which was addressed to each of these electric coils in the output signal of a magnification means and which carries out bias value part bias -- It reaches. the 2nd energized to each electric coil by the energization duty corresponding to the signal by which bias was carried out, m+2, 2m+2, and .... coil driver (615 to 621; 42 of

62, 65, and 68, 411-414 of 45 and 48); -- the signal (calcium correspondence) of the 3rd ream the m-th, 2m, 3m, and ... an electric coil (1calcium, 2calcium, 3calcium) -- a magnification means to amplify with the amplification factor which was alike, respectively and was addressed, and the means which was addressed to each of these electric coils in the output signal of a magnification means and which carries out bias value part bias -- and the m-th energized to each electric coil by the energization duty corresponding to the signal by which bias was carried out, 2m, 3m, and ... it has coil driver (615 to 621; 43 of 63, 66, and 69, 411-414 of 46 and 49);.

[0012] In said one example of this invention, each electric coil is linear motor energization (for driving metal flow) by m phase (example m= 3) alternating current, and in order to add the direct current for braking to this, an electric coil energization current value is determined by energization duty control. The change of a time series change of energization duty and an energization polarity is also hung down. [wave / alternating current] The alternating current wave form of the amplitude corresponding to necessary flow driving force is obtained by carrying out the multiplication of the amplification factor to a series of energization duty which brings about a basic alternating current wave form. A multiplication means performs such amplitude adjustment or a setup by each electric coil correspondence. An in one direction flowed part for braking is superimposed on an alternating current wave by adding energization duty (it being constant value at time series) corresponding to the direct-current value for braking to the energization duty which acquires the alternating current wave for linear motor energization (it subtracting on parenchyma, if this energization duty is made into the negative value), this energization duty -- large -- /-- by making it small, an in one direction flowed part corresponding to necessary damping force is obtained. An addition means performs such level (bias) adjustment or a setup by each electric coil correspondence. In this embodiment, the alternating current of the request amplitude for a flow drive, direct currents of the request level for braking, and those composition are performed by data processing of energization duty, and an electric coil energization circuit becomes very easy.

[0018] A function generator 81 gives a series of energization duty data which gives alternating-sine-wave(for example, Aa of drawing 7)-like change of current along time series, to the energization pulse generators 61, 64, and

67 in the 1st set. A function generator 82 gives a series of energization duty data which gives alternating-sine-wave(for example, Ba of drawing 7)-like change of current along time series, to the energization pulse generators 62, 65, and 68 in the 1st set. A function generator 83 gives a series of energization duty data which gives alternating-sine-wave(for example, Ca of drawing 7)-like change of current along time series, to the energization pulse generators 63, 66, and 69 in the 1st set.

[0021] With reference to drawing 6, the pulse which a pulse generating circuit 90 generates is explained. When Is in drawing 6 is assumed as the alternating current wave form for a molten steel flow driving, a pulse generating circuit 90 generates the clock pulse Pd of a very short period to a round term of alternating current wave Is. And it (i.e. pulse generating circuit 90) divides the clock pulse Pd and generates the energization timing pulse Pa which specifies a round term of duty energization, Pa also being of a short paddle period to a round term of Is. It also divides the pulse Pa and generates the 1st alternating current period synchronization pulse Pbo which specifies a round term of the alternating current wave form Is. A circuit 90 further counts pulse Pa on the basis of pulse Pbo, matches wave Aa in drawing 7 with alternating current wave Is, and then generates 2nd, 3rd, 4th, 5th, and 6th alternating current period synchronization pulses P_{b120}, P_{b240}, P_{b180}, P_{b60}, and P_{b300} for generating the waves Ba, Ca, Ab, Bb and Cb (drawing 7), delaying from Aa in phase of 120 degrees, 240 degrees, 180 degrees, 60 degrees and 300 degrees, respectively. These pulses are given to function generators 81-86 as shown in drawing 5 and the energization pulse generators 61-69, and 71-79.

[0023] Although the configuration of function generators 82-86 is the same as the configuration of 81, since the 2nd alternating current period synchronization pulse P_{b120} is given to a function generator 82 and the address counter (not shown) is cleared by this as shown in drawing 5, and since P_{b120} is behind Pbo in about 120 degrees of phases, the electric coil energization current based on energization duty data which a function generator 82 generates serves as Ba of drawing 7, when the electric coil energization current based on energization duty data which a function generator 81 generates serves as Aa of drawing 7, for example. Since the 3rd alternating current period synchronization pulse P_{b240} is given to a

function generator 83 and the address counter (not shown) is cleared by this, and since P_{b240} is behind Pbo in about 240 degrees of phases, the electric coil energization current based on energization duty data which a function generator 83 generates serves as Ca of drawing 7. Currents (waves) which flow to electric coils based on energization duty data which these function generators 81-83 output are as follows as mentioned later in outline. Aa (81 outputs) flows to coils 1Aa, 2Aa and 3Aa shown in drawing 1, Ba (82 outputs) flows to electric coils 1Ba, 2Ba and 3Ba, and Ca (83 outputs) flows in electric coils 1Ca, 2 Ca and 3 Ca. Therefore, the field which moves to the left (-y) from the right (+y) along the long side 1 of mold by the magnetic poles 11-19 of the 1st set acts on the molten metal in mold.

[0024] Since the 4th alternating current period synchronization pulse Pb180 is given to a function generator 84 and the address counter (not shown) is cleared by this, and since Pb180 is behind Pbo in about 180 degrees of phases, when the electric coil energization current based on energization due teddy-TA which a function generator 81 generates serves as Aa of drawing 7 , the electric coil energization current based on energization due teddy-TA which a function generator 84 generates serves as Ab of drawing 7 . Since the 5th alternating current period synchronization pulse Pb60 is given to a function generator 85 and the address counter (not shown) is cleared by this, and since Pb60 is behind Pbo in about 60 degrees of phases, the electric coil energization current based on energization due teddy-TA which a function generator 85 generates serves as Bb of drawing 7 . Moreover, since the 6th alternating current period synchronization pulse Pb300 is given to a function generator 86 and the address counter (not shown) is cleared by this, and since Pb300 is behind Pbo in about 300 degrees of phases, the electric coil energization current based on energization due teddy-TA which a function generator 86 generates serves as Cb of drawing 7 . Bb is behind in about 120 degrees of phases to Cb, and notice Ab about the point which is behind in about 240 degrees of phases to Cb.

Currents (waves) which flow to electric coils based on energization duty data which these function generators 84-86 output are as follows as mentioned later in outline. Ab (84 outputs) flows to coils 4Ab, 5Ab and 6Ab shown in drawing 1, Bb (85 outputs) flows to electric coils 4Bb, 5Bb and 6Bb, and Cb (86 outputs) flows in electric coils 4Cb, 5Cb and 6Cb. Therefore, the field which moves to the right (+y) from the left (-y) along the long side 2 of mold by the magnetic poles 21-29 of the 2st set acts on the molten metal in mold.

[0031] By the above configuration, to electric coils 1Aa, 2Aa and 3Aa shown in drawing 1, the current which adjusted the amplitude of the current wave form Aa (81 outputs) shown in drawing 7 and direct-current bias for every electric coil flows. To electric coil 1Ba, 2Ba and 3Ba the current which adjusted the amplitude of the current wave form Ba (82 outputs) shown in drawing 7 and direct-current bias for every electric coil flows. In electric coil 1Ca, 2Ca and 3 Ca, the current which adjusted the amplitude of the current wave form calcium (83 outputs) shown in drawing 7 and direct-current bias for every electric coil flows. Therefore, by the magnetic poles 11-19 of the 1st set, the magnetic field which moves to the left (- y) from the right (+y) along the long side 1 of mold acts on the molten metal in mold changing magnitude for every magnetic pole. And moreover, the braking field (static field) from which magnitude differs for every magnetic pole acts on molten metal.

[0032] Similarly, to electric coil 4Ab, 5Ab and 6Ab shown in drawing 1, the current which adjusted the amplitude of the current wave form Ab (84 outputs) shown in drawing 7 and direct-current bias for every electric coil flows. To electric coil 4Bb, 5Bb and 6Bb shown in drawing 1, the current which adjusted the amplitude of the current wave form Bb (85 outputs) shown in drawing 7and direct-current bias for every electric coil flows. To electric coil 4Cb, 5Cb and 6Cb shown in drawing 1, the current which adjusted the amplitude of the current wave form Cb (86 outputs) shown in drawing 7 and direct-current bias for every electric coil flows. Therefore, by the magnetic poles 21-29 of the 2nd set, the field which moves to the right (+y) from the left (- y) along the long side 2 of mold acts on the molten metal in mold changing magnitude for every magnetic pole. And moreover, the braking field (static field) from which magnitude differs for every magnetic pole acts on molten metal.